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REPORT
CD NO.

50X1-HUM

COUNTRY	USSR	DATE OF INFORMATION	1949
SUBJECT	Scientific - Chemistry, filtration		
HOW PUBLISHED	Bimonthly periodical	DATE DIST.	22 Aug 1950
WHERE PUBLISHED	Moscow	NO. OF PAGES	2
DATE PUBLISHED	Sep-Oct 1940	SUPPLEMENT TO REPORT NO.	
LANGUAGE	Russian		

THIS IS UNEVALUATED INFORMATION

SOURCE Kolloidnyy Zhurnal, Vol XI, No 5, 1940.

FLOW OF VISCOUS-PLASTIC DISPERSE SYSTEMS IN PIPES UNDER CONDITIONS OF VARIABLE VISCOSITY AND LIMITS OF SHEARING STRESS IN USSR

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Submitted 14 Feb 1949

Hitherto, in the treatment of problems in the field of hydrodynamics of colloids and of those pertaining to the flow of viscous-plastic disperse systems, viscosity and the limit of shearing stress have been always regarded as having a constant value throughout the body of the liquid. In the case under consideration, the filtration of peat flowing under pressure through a porous pipe is envisaged. The water is gradually pressed out through the walls of the pipe, so that the rate of mass transport diminishes toward the far end of the pipe. This is essentially the construction of the filter press for peat proposed by Tsuprov. Under the conditions in question, peat in the first approximation may be regarded as a viscous-plastic substance of the Bingham type, an assumption which is close enough to experimental facts.

The rate of reduction of mass transport can be determined from the mass leaving the exit end of the pipe per unit of time, and the initial velocity of flow. The flow is wholly laminar: the only gradient of velocity is along the axis of the pipe z.

1. Flow Through Pipe With Circular Cross Section, Changing Its Viscosity Only

For some disperse systems, even at high concentrations, the limit of shearing stress is extremely low and may be assumed to equal zero. Under those conditions, it follows from the Navior-Stokes equations that the velocity of flow v can be expressed as a function of: the radial distance r from the center of the pipe of radius a (such that v equals o when r equals a); velocity gradient along the pipe's axis; pressure difference p'-p; viscosity integral; and the distance z along the pipe's axis.

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Hence the volume Q of mass flowing through the cross section of the pipe per unit of time can be expressed as 2 pi times the integral of the product vr taken with respect to r from r equals o to r equals a. (If k equals o and the coefficient of viscosity is assumed to be a constant, Poiseuille's Law is obtained.)

Q depends on z and varies throughout the length of the pipe. This circumstance is brought about by the filtration of water through the walls of the pipe and is not due to any compressibility of the disperse mass in the present case.

2. Flow Through Pipe With Circular Cross Section, Under Conditions of Both Changing Viscosity and Limit of Shearing Stress

For viscous-plastic substances which do not flow through a pipe unless the shearing stress exceeds a certain value, a different expression is obtained for the velocity of flow v, and, as before, the volume Q of mass if found by a suitable integration, involving the limit of shearing stress, theta.

From this one can easily calculate the pressure drop along the length of the pipe, namely, the negative derivative of pressure p with respect to the axial distance z (i.e., minus dp/dz).

3. Flow Through Pipe With an Annular Cross Section, Changing Its Viscosity Only

If theta, the limit of shearing stress, is neglected, we obtain another expression for the velocity of flow v, and hence a different volume Q of mass flowing through the pipe per unit of time.

In the special case when k equals o and the viscosity is constant, the formula of mass transport (mass expenditure) developed by Academician Leybenson is obtained (L. S. Leybenson, Petroleum Technology Mechanics, Part 1, 25-26, 1937). Using the methods applied in the mathematical calculations mentioned above, expressions for v and Q with variable theta can be obtained for the case of flow in a pipe having an annular cross section.

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